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The Role of Biological Assessment in Effluent Control

D. I. Mount

U.S. Environmental Protection Agency

Environmental Research Laboratory-Duluth

5201 Congdon Boulevard

Duluth, Minnesota 55804

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16. ABSTRACT

The U.S.E.P.A. issued a water-quality based policy in March, 1984 which includes control of toxicity in effluents if receiving water impact occurs. Toxicity tests can be used to measure toxicity, estimate additional removal necessary to avoid impact, establish permit limits and for compliance monitoring. Toxicity tests are a direct measure of the effect for which control is sought and often are cheaper than chemical analyses.

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This workshop, as indicated by the title, is to examine the state of the art of using biological measurements to assess and control the biological impact of effluents discharged to surface waters. The conference organizers hope that the proceedings of the conference will identify the currently available techniques that are reasonably well proven as reliable ones and identify where we yet need development of additional methods or approaches to better use biological measurements for control purposes.

I would like to tell you about some recent progress in the U.S.A. in validating the predictability of effluent tests to predict the receiving water impact of complex effluents. I would also like to tell you about plans in the U.S. EPA to use effluent tests to limit the discharge of "toxicity" as a control requirement without specifying the substances causing the toxicity. As I describe these programs I am sure controversial issues will emerge that will provide discussion stimulus for this conference.

You should bear in mind that all of my comments stem from the situation and regulatory framework that now exists in the U.S.A. To the extent that these are different in other countries, may change the desirability or workability for those places where conditions are different. I would hasten to point out however that at least the regulatory framework is manmade and therefore can be changed. I firmly believe that it is our duty as scientists concerned with the quality of surface water and the ecosystem contained therein, to press for changes in the existing regulatory framework where we have reason to believe there is a better way to regulate. This conference occurs at a time of great satisfaction for me because some of the approaches I have long supported for control of complex effluents are now being implemented. I have had the privilege of working with some of the prominent names in water pollution efforts in this country of past years. I refer

especially to Dr. Peter Doudoroff and Dr. Clarence Tarzwell who contributed so much to the thinking of this field in years past. I am sure much of my philosophy and approach was gleaned from them and I hope that I can be a part of the effort that implemented some of their early but excellent ideas about effluent control.

At this point I need to diverge, briefly I hope, to be sure you are aware of some of the salient features of the past 15 years of water pollution legislation and abatement progress in the U.S.A. The reason for this divergence is so that you will be better able to understand the reasons for some of our decisions and future plans.

Beginning in the early 1970s, the U.S.A. set forth on a program to require all dischargers to have a permit to discharge effluents into surface waters. Further, every discharger was to be required to install a specified degree of treatment whether the untreated discharge caused an adverse effect or not. It is important to note that the amount of treatment required had no relationship to the receiving waterbody - it was a uniform treatment requirement based on available treatment technology and its cost.

In addition, where that amount of treatment did not result in the elimination of adverse effect on the receiving water, additional treatment was to be required. I was not a party to the discussions that resulted in the decision but I am told that in part the reason to take this approach was that receiving water quality standards were too few, too controversial and too costly to enforce.

The uniform treatment approach set in motion what must have been the largest construction effort to build wastetreatment plants for the 70,000 plus discharges in the U.S.A. that has ever occurred anywhere. The legislation also said that while this construction was in progress, higher levels of

treatment were to be defined and required in the decade of the 1980s. The original level of treatment has largely been completed and the main effort was to remove BOD, solids, control pathogenic bacteria and a few other commonly occurring pollutants. This treatment, although not primarily focused on removal of chemicals, especially organic chemicals, is as a side benefit removing a large amount of them. As a result a great many of our effluents no longer have a measurable acute toxicity. However, a substantial percentage do have measurable toxicity, especially chronic toxicity.

We are now to the time when the higher level of treatment is to be required. These higher levels termed "Best Available Treatment" (BAT) have been defined for some types of discharges but not for all types. Further, for some the cost is very high or the additional removal does not seem to warrant the cost. In early 1984, the U.S. EPA issued a "Water-Quality Based Policy" which places emphasis on giving priority attention to those discharges which are thought to be having the largest adverse impact on the receiving water rather than only blanket uniform treatment for all discharges. The policy further states that toxicity will be controlled in effluents as well as other characteristics. Toxicity limitation, is the part of the policy which is of great interest to me and is closely related to the subjects to be discussed by the participants of this conference. It is also completely consistent with some of the basic goals set forth in our Water Act which state that toxic pollutants in toxic amounts are to be prohibited and in another goal that among other things all waters are to be "fishable".

We currently have very few discharge permits which expressly limit toxicity emission in effluents although there are considerably more permits which require toxicity to be measured but do not limit the degree of toxicity. I have been involved in a research effort for the past several

years to determine how well some effluent tests currently available will predict biological impact in the receiving water. I would now like to describe for you some of the insights and results we have gained in this effort.

Even though much pollution abatement effort is done for the protection of toxicity to aquatic life, the treatment systems required were rarely, in fact almost never, evaluated to see how much toxicity was removed. Little wonder then that many treatment plant effluents still are toxic. Of course the immense increase in synthetic organic chemical usage in recent years has contributed to this situation. At this point I should emphasize that it is the full intent of EPA to limit toxicity without expending the effort to identify the specific substances causing the toxicity. Many scientists and regulators are surprised or even disbelieving that limitation of toxicity is feasible without identification of the causative agents. Their attitude is of even greater surprise and disbelievement to me! After all did we ever or do we now need to know the specific components of suspended solids in order to remove them in treatment? Did we or do we now insist on knowing the specific components causing BOD before we can require its removal? Do we insist on knowing the specific chemicals that cause TOC (total organic carbon) before we place a limit on its discharge? The answers to the above questions are, "of course not" and limiting toxicity of an effluent is no different. "Generic" treatment requirements are commonly used.

For some reason many people seem to feel toxicity is different and the specific chemicals causing it must be identified. A reason sometimes given for this position is that we do not know how to design treatment systems to remove toxicity. There are several responses to this statement. Perhaps most forceful is that the way we learned how to remove BOD, SS and TOC was to

try various treatment methods on various wastes and see how good the removal was. Toxicity removal can be determined exactly the same way. Now obviously some allowance of time will have to be given for this determination but we will never learn how to remove toxicity if we do not have the forcefulness to require its removal. At least in the U.S.A. and I suspect in some other countries as well, the regulatory agency does not specify how to remove toxicity or any other effluent characteristic. This discretion is left to the discharger. I mentioned earlier that even the relatively basic treatment now in place in the U.S. has removed much, very much toxicity. There is nothing to prohobit any discharger from consulting with other dischargers who do not have a problem to learn how removal might be accomplished. Furthermore, in my experience, dischargers are often very adept at locating probable in-plant sources, especially if a little persuation is added! Someone, whose name I cannot now recall once said, "It takes some courage as well as knowledge to abate water pollution."

While I see little short-term value in fractionating effluents as a chemical analyst would do, that is acid extractables, base extractables, etc., I see a lot of value in what I like to call waste engineering fractionation. By this I mean fractionating effluents using techniques that are directly relateable to waste treatment methods that might be employed. For example it takes little imagination or resources to run a sample of effluent through a bench scale carbon filter or to try a bench scale air stripping technique to see if toxicity is removed by such procedures. If it is, a treatment alternative becomes immediately obvious that will remove toxicity without identifying the causative agents. Frequently, some simple housekeeping procedures are found that remove the problem, especially where there is a good suspicion as to the source.

I am sure some of you who are chemists are saying "Why not just analyze the effluent and see what it contains?" There are several replies to this question. First, if anything beyond a very simple analytical measurement is needed, the cost of effluent toxicity tests now available is at least an order of magnitude less than the chemical analyses and if a complex analyses is needed, such as GC-MS, then the toxicity tests will be 2 or 3 orders of magnitude less. Even setting cost aside as a concern, a chemical analysis of a complex waste will usually show 10's, 100's or 1000's of substances present. One certainly cannot assume the substances at highest concentration are the problem. Neither will one have data on what the toxic concentrations are for more than a few in the list. And finally you will probably have no knowledge about which ones may be in a biologically active form or what ones will display interactions, either positive or negative.

I am sure the biologists are saying, "Why not use field biological surveys to measure impact rather than toxicity tests and avoid the necessary extrapolation?" The answer is much the same as for the previous question. The cost of a good biological survey is at least 2 and probably more than three orders of magnitude greater than toxicity tests in all but the simplest situations and smallest receiving water. Second, if there are multiple dischargers, the most common situation by far in the U.S., there is no chance to determine which discharge is causing how much effect except in rare instances and one certainly cannot measure how much toxicity reduction should be required to alleviate the problem. Thirdly, even the best field surveys fail to detect any but the the more gross effects due to toxicity so impacts must be large to detect their presence and finally, field studies require that the adverse impacts have ocurred in order to measure them and therefore are not useful for treatment decisions on new discharges.

I want to emphatically state that I nor others in the U.S. feel that we do not need chemical analyses, single chemical criteria or biological surveys. Chemicals that persist in the environment for long periods and are found in many places or in many non-point sources are best managed by single chemical criteria (standards). Chemical analyses, especially for groups of chemicals can often help to find the cause of toxicity and a treatment alternative. And biological surveys have a critical function to provide insight into long-term trends and the overall health of large reaches of receiving waters. Data from these types of measurements are hard to translate into permit language and we are saying, toxicity should be limited too.

Neither will toxicity tests on effluents provide all of the answers needed for control purposes. Changes in equilibrium resulting from fate processes, time and dilution are likely to be poorly estimated. Available tests for human health concerns are very poor for predicting health effects except for bioconcentratable substances. And such tests are not likely to be useful for substances that concentrate in sediments.

Many of us in the U.S. feel that the limitation of toxicity in effluents will move us a giant step forward in a cost-effective way to further reduce the emission of toxicity where it is likely to be of most concern. We see this limitation as a supplement to and not a replacement for more conventional control requirements.

In our research efforts to evaluate the validity of effluent toxicity tests we have completed studies in many geographic areas of the country and many types of receiving waters and effluents. Our objective has been to measure effluent toxicity and based on these toxicity tests predict what concentrations of effluent should cause impact in the stream. By doing dye

injection studies we calculate the ambient effluent concentrations and then establish stations for biological sampling where various effluent concentrations occur. The measured impact is compared to the predictions to see if the effluent toxicity tests were valid predictors.

We also devised what we call an ambient toxicity test. In these tests we take water samples from the receiving water and measure the toxicity. The results of these tests can be compared directly to the biological field data and also to the effluent tests if the effluent concentration is known at the location where the sample is taken. Thus a three-way comparison can be made to see how good the agreement may be. These ambient tests were originally devised to measure the persistence (or die-away) of toxicity. They have proven to be extremely valuable tests for a variety of purposes including as a broad survey tool to identify segments of water bodies having toxicity, to locate new point sources of toxicity, to identify upstream water quality problems and to verify effluent toxicity test results. This test was made possible as a result of the development of short, chronic tests that can be performed with approximately the same effort as for a 96 hour acute fish toxicity test. Ceriodaphnia dubia/affinis is one test organism and a full life cycle test can be completed in 7 days elapsed time. The working time is about 6 hours for the entire test if 5 treatments and a control are used. Thus for ambient testing, if stations are placed 16 kilometers apart, 160-200 kilometers of stream can be assessed for toxicity with less than 2 person-days of effort not including sample collection time.

We have also used a 7-day larval growth fish test as a second estimate of toxicity. We use the fathead minnow but many species of fish will work as well. This test is also 7 days and we routinely get 4-6 fold weight increase in 7 days which is ample to weigh accurately. This test has proven to be

very sensitive as well. The data from the studies we have completed clearly show the need to do at least two species. Frequently one or the other species has been insensitive to the toxicity displayed by the second species.

Figure 1 shows the correlation between the ambient toxicity (young/female) and benthic community loss, diversity and number of species. Figure 2 shows a similar correlation for algal diversity. There was poor correlation with the fish community because the fish were much less sensitive to one of the three effluents, than were the Ceriodaphnia. Figures 3 and 4 show plots comparing ambient toxicity as measured in the laboratory tests with the number of species and taxa of benthos and fish for two successive years.

Considering that the community measurements reflect the last several months of exposure variation whereas the toxicity is based on 7 days of sampling in one year and one day in the other year and also considering the effect of habitat differences on the community measurements, we feel the results are in excellent agreement. We are completing the reports for studies finished at other locations and the predictability has been comparable at these sites. In the studies where dye injection was done and effluent concentrations are known, the effluent dilution tests were also accurate predictors of instream impact.

We feel that all of our studies clearly support the validity of effluent and ambient tests for predicting community impact. Of course the more species that are tested the better the prediction will be. Several authors have examined the question of the benefit gained by testing additional species. Blanch (1984) found that some species of algae are more useful as representatives of species groups than others. He agrees that a few well

chosen test species can provide good estimates of species sensitivity with reasonable confidence. We feel that the good correlations we have found between test species and impact on the community suggests that the Ceriodaphnia and fathead are a good choice for effluent testing. There will always be cases in which impact will be underestimated if only a small number of species are tested. No species is always the most sensitive. However, practicality limits testing to a small number of species. An additional amount of protection is provided if, as is the case in the U.S.A., limits are based on a critical, very low flow. If this is done then the duration during which the maximum exposure occurs is relatively short.

Most substances found in effluents are not as persistent as the chemicals that have been so problematical such as DDT and PCBs. To the extent that the substances in effluents decay, toxicity decreases and the area of exposure is smaller. Most of the effluent toxicity testing in the U.S. has not considered factors that diminish the real world exposure, such as persistence and application of limits that are protective at low flow, but have measured only toxicity. In order for impact to be underestimated several events must occur together otherwise there is enough safety margin inherent in the limits and the way they are applied to protect.

In the 8-10 sites we have studied in our recent effluent testing program, some surprises have been encountered. In no case have we seen synergism, only rarely have we found additivity and negative interaction has been common. Antagonistic effects have played a very important role in altering toxicity. One reason these effects have not been more often reported may be because most effluent testing has been done in relatively pollutant-free water for dilution. Since our objective has been to predict impact below outfalls, we have used dilution from immediately upstream even

if it contained high concentrations of other effluents. Failure to use such dilution water is likely to over-estimate toxicity and cause one to conclude that effluent tests are not good predictors of impact in the receiving water.

Based on our experiences during the past 3 years, we believe knowledge is far enough advanced to make toxicity control practical and a better alternative in some instances than previously used practices. We see toxicity control as a supplement to and not a replacement for single chemical limitations in permits. We feel that such limitations are necessary in addition to single chemical ones because of the large number of chemicals in use and the slow progress in developing limits for single chemicals.

There is a pressing need for methods to measure the persistence of toxicity at an economical cost in order to avoid excessive limitations based only on toxicity. There is also a pressing need for a better comprehension of fluctuating exposure effects. Since effluent characteristics vary over time and dramatically so for some, the conventional constant exposure data customarily developed may not be applicable in some instances.

Finally, the way in which limits are translated into control requirements has an immense bearing on how stringent or protective the limits turn out to be. For instance if no effect levels are applied to a very low flow that happens only infrequently, the maximum permissible concentration will seldom occur. The regulatory strategy must be considered as a part of the limitations just as much as the way in which the toxicity tests are conducted and the data are interpreted.

References

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Mount, D. I., N. A. Thomas, T. J. Norberg, M. T. Barbour, T. H. Roush, and W. F. Brandes. 1984. Effluent and ambient toxicity testing and instream community response on the Ottawa River, Lima, Ohio. U.S. Environmental Protection Agency, Duluth, Minnesota. Publication No. EPA-600/3-84-080.

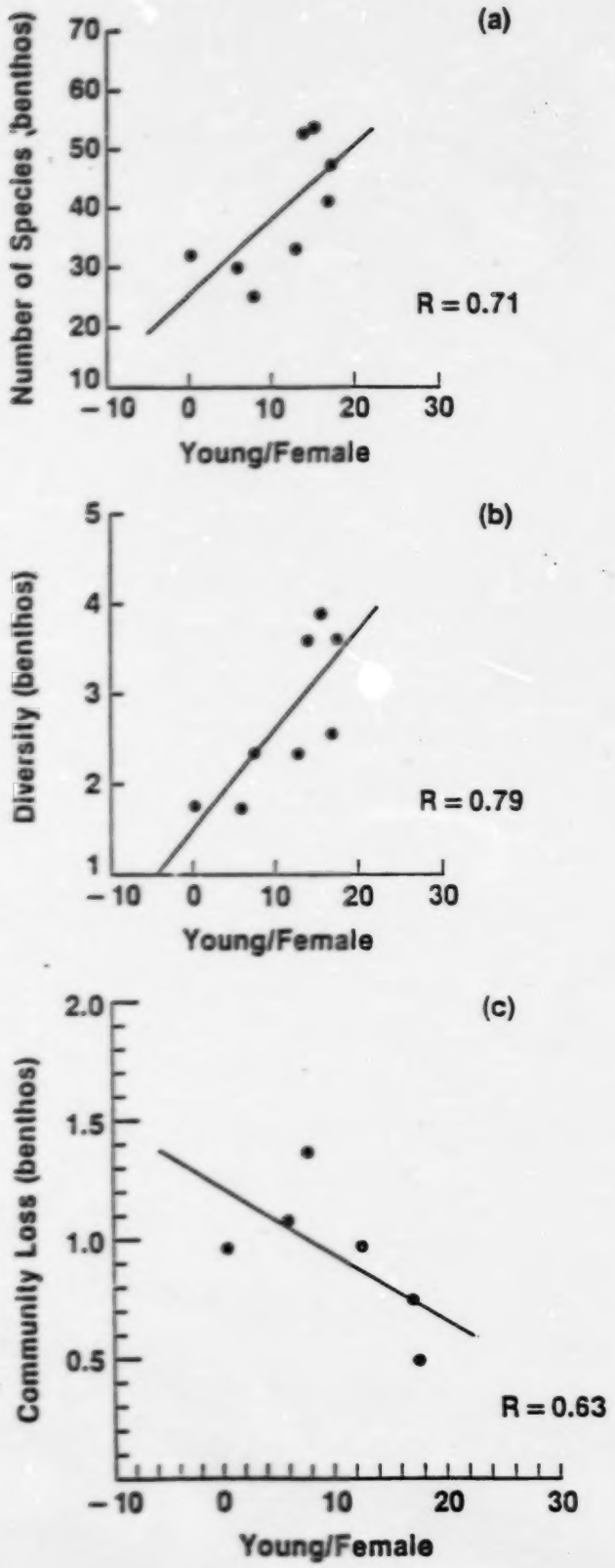


Figure 1. Correlation of Ceriodaphnia young per female with benthic parameters from eight stations in the Ottawa River, Lima, Ohio, 1982. (Mount et al., 1984)

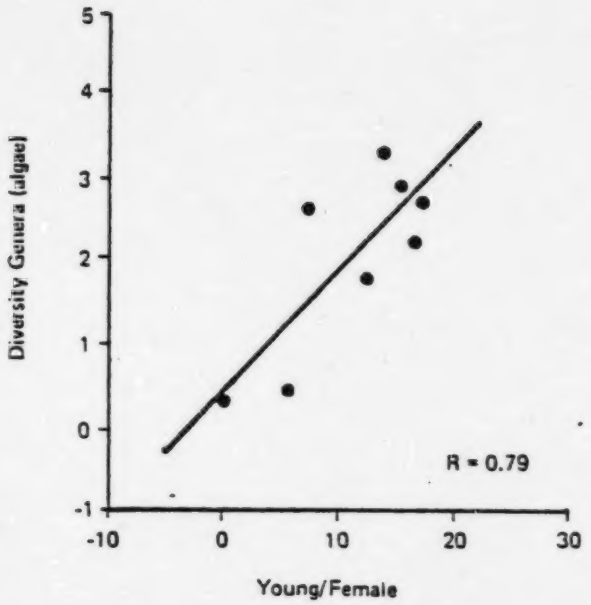


Figure 2. Correlation of Ceriodaphnia young per female and algal diversity at eight stations in the Ottawa River, Lima, Ohio, 1982. (Mount et al., 1984)

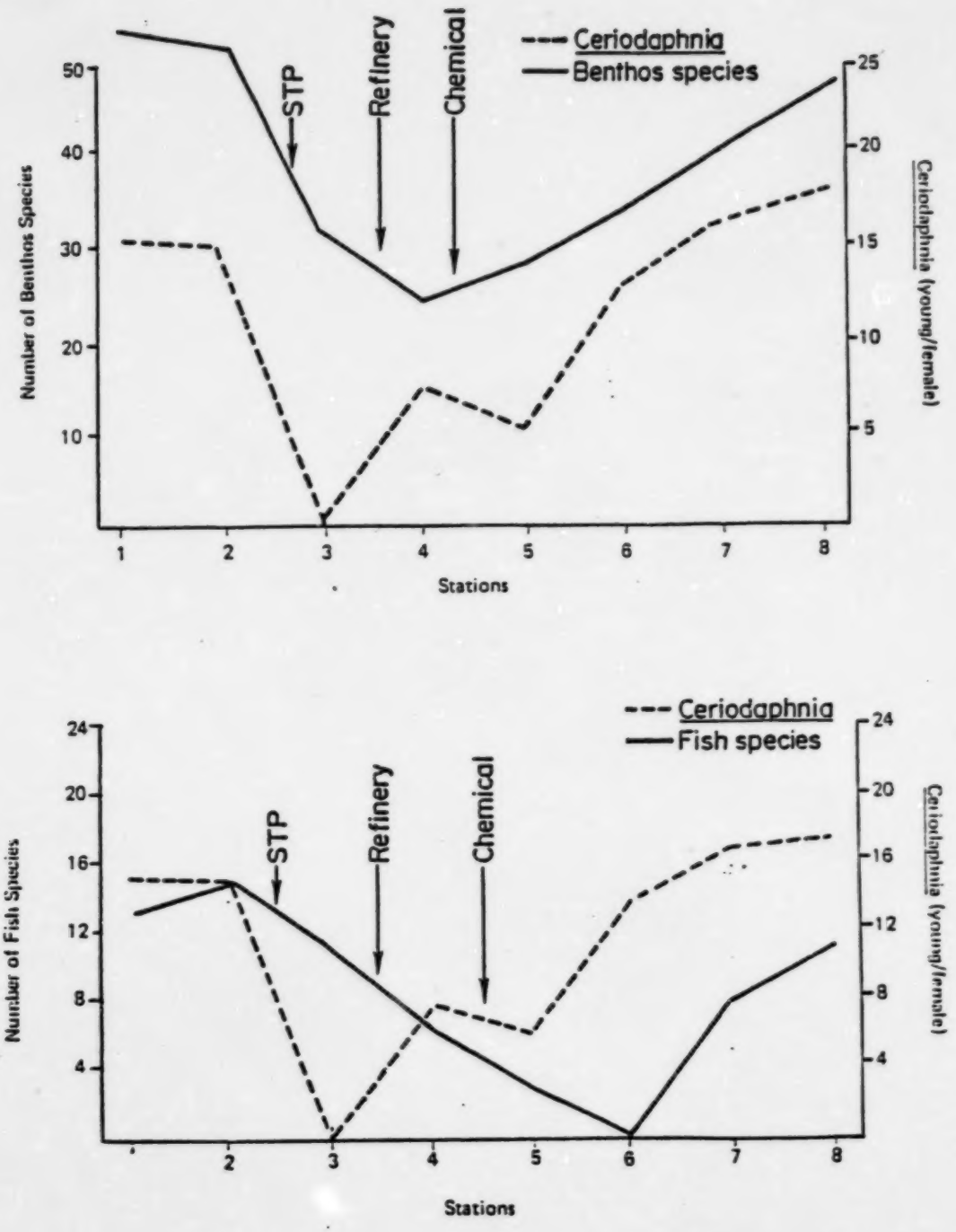
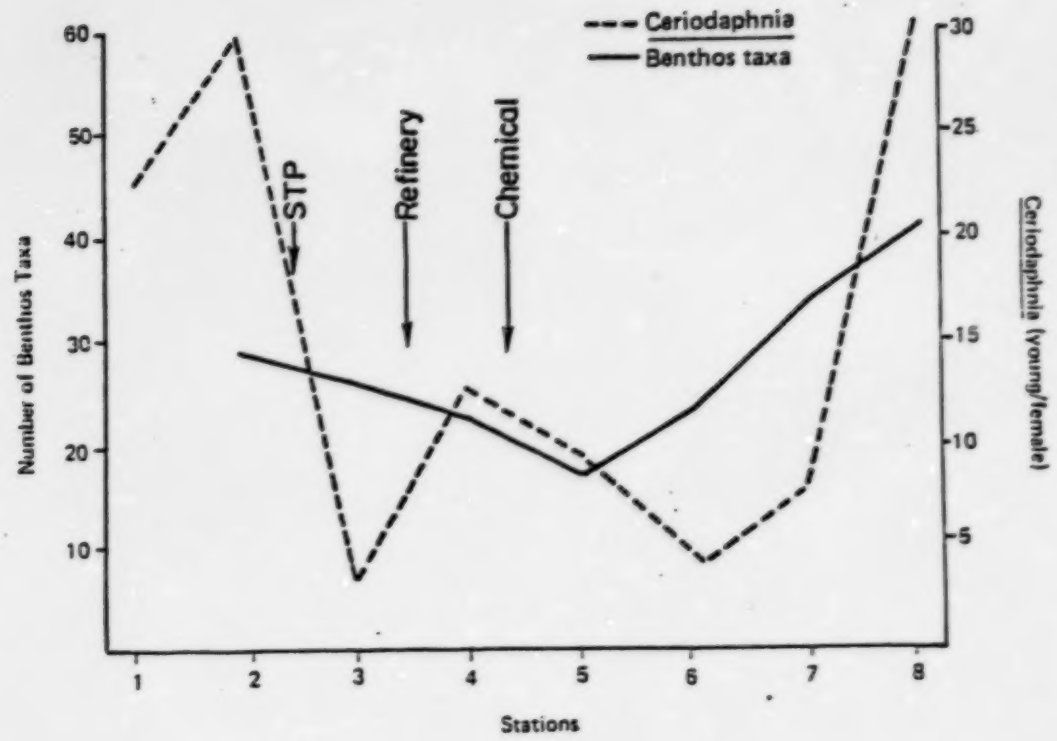


Figure 3. Ambient toxicity correlation between Ceriodaphnia young per female and ecological survey data for 1982. (Mount et al., 1984)



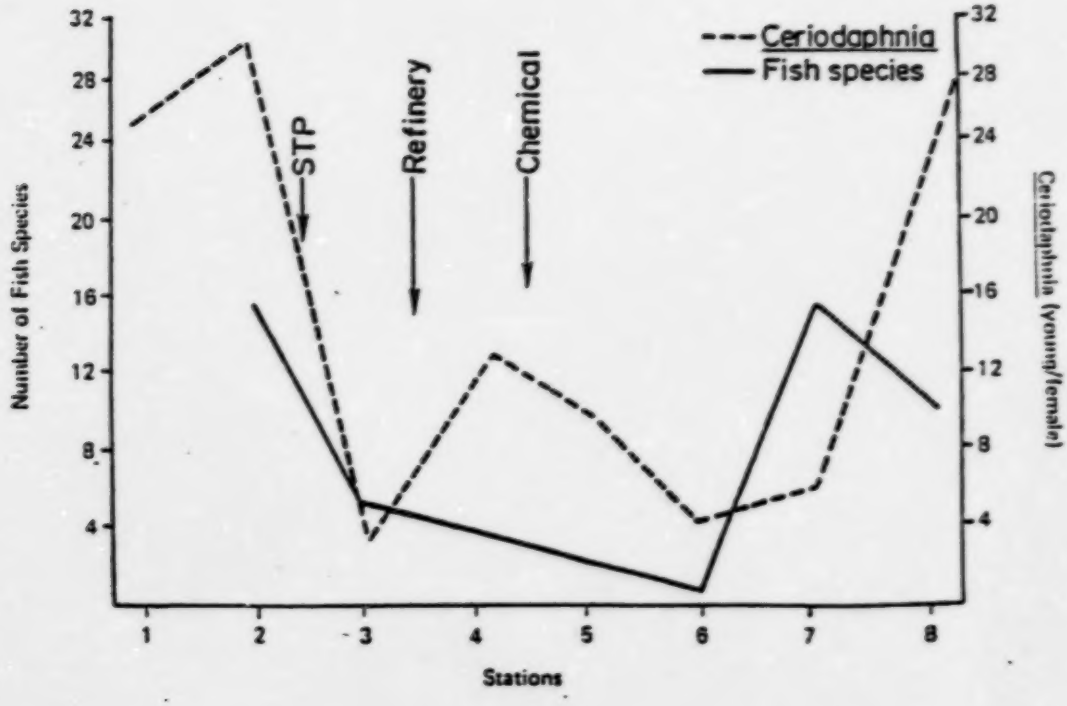


Figure 4. Ambient toxicity correlation between Ceriodaphnia young per female and ecological survey data for 1983.
(Mount et al., 1984)